THE CONSTRUCTION OF A GAS-FIRED KILN USING LOW-DENSITY BRICKS COMPOSED FROM MFENSI CLAY FOR SCHOOLS

By

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DECLARATION

I hereby declare that this submission is my own work towards the MA degree and that to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

The acquisition of kilns for firing student's clay works has been a difficult problem for most Senior High Schools and other users of kilns in the educational sector. The 0.42m³ capacity kiln was designed and built with locally obtainable raw materials, locally composed low-density bricks and mortar, and locally manufactured gas burners rated at160000 joules. This is a solution for schools teaching and learning pottery and ceramics as an elective subject. Institutions whose work and activities require the use of kilns will also find this handy. High pressure regulators were fitted onto the 15kg gas cylinder to enable regulation and delivery of high gas pressure to the burners for combustion. A solution has been found in the business of kilns construction with very efficient heat maintenance properties for firing clay products, giving rise to increase in temperature and even distribution of heat is available in bringing green ware to a point of maturity (bisque) at 1100°C.Mfensi clay mixed with sawdust serves as a very useful ceramic material for the production of low-density bricks for the construction of a gas-fired kiln. Recommendations have been made for the production of locally manufactured gas kilns in Ghanaian schools.

Table of Contents

LIST OF PLATES

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 Overview

This chapter provides the basic framework of the whole thesis. It embodies the background to the study, statement of the problem, objectives of the research, research questions, delimitations, limitations, definition of terms, importance of the study and organization of text.

1.2 Background to the study

A kiln is any of several kinds of furnace, heated electrically or by the combustion of fuel, used to fire pottery or other ceramic products, to roast ores, or in the production of cement. In modern engineering usage, little distinction is made between a furnace and a kiln, although the term kiln is always applied to the heating units used in ceramic and cement manufacture. Kilns are essential in the teaching and learning of ceramic art. Without kilns, the conversion of dry clay into stone or hard biscuit ware will not be achieved. Kilns in general are of two types: Intermittent Kilns, in which the fire must be extinguished while the kiln is being unloaded and recharged with another batch of material to be fired; and Continuous Kilns, in which loading and unloading is accomplished while the kiln is lit. Modern kilns are of both types, although the various forms of continuous kilns are particularly suited to mass production manufacture.

1.3 Statement of the problem

In senior high schools, intermittent kilns are supposed to be provided for the firing of ceramic works produced by students. Most schools in the Ashanti region of Ghana such as the Yaa Asantewaa Senior High School, where teaching and learning of ceramic art is done, do not have kilns for the firing of their works. The cost of imported kilns is so high that most schools cannot afford to import or buy one. The researcher is of the belief that, there is the possibility of constructing intermittent kilns using locally composed low-density bricks from clays obtainable and available to the schools. Unfortunately most teachers of ceramic art do not have the requisite knowledge and skill in composing the local earthenware clay into low-density bricks for kiln construction. Experiments conducted indicate the possibility of composing low-density bricks using Mfensi clay which can be employed as heat retention materials for the construction of a kiln for the firing of ceramic wares produced by students of Yaa Asantewa Girls Senior High School.

1.4 Objectives of the Project

In addressing this problem of unavailability of a kiln in Yaa Asantewaa Girls Senior high School, the researcher set the following objectives

1. To study the methods and processes in composing low-density bricks from local earthenware.
2. To compose low-density bricks from Mfensi clay.
3. To use the composed bricks for the construction of a gas-fired kiln.

4. To use the constructed gas-fired kiln for the firing of ceramic wares and evaluate its effectiveness.

1.5 Research questions

1. How can Mfensi clay be used for the composition of low-density bricks?
2. Will the Mfensi clay be appropriate for kiln construction?

1.6 Delimitation

The study is limited to the design and construction of a gas kiln using Mfensi clay and sawdust.

1.7 Limitations

The researcher did not have access to temperature measuring devices and other accessories necessary for monitoring the firing schedule and testing the kiln's efficiency.

1.8 Definition of Terms

To facilitate understanding of the project, technical terms used in the study are explained as follows:

Bisque firing: Preliminary firing done to harden the clay body, prior to glazing and subsequent glaze firing.

Clay bodies: A mixture of clay and sawdust.

Chimney: A channel for the escape of exhaust gases

Damper: A facility for controlling draft system of the kiln.

Firings chamber: The part of the kiln where fire is set to heat up the wares.

Green ware: Clay ware that has not been fired.

Insulating bricks: Specially composed low-density bricks used in areas where heat retention is required.

Kiln: A box made of poor heat-conducting bricks for firing ceramics.

Kiln chamber: The area in the kiln where wares are packed for firing.

Low-density brick: These are highly porous bricks use for heat retention in kilns.

Mortar: Composition of materials used in giving level in brick laying in kiln construction.

1.9 Importance of the study

1. The study has provided information on alternative raw materials for kiln construction.
2. It has drawn attention to available raw materials for kiln construction for Ghanaian schools.

3. This Project has provided Yaa Asantewaa Girls Senior high School with a gas kiln.

4. The report on the study will serve as a reference material for further studies.

1.10 Organization of the rest of text

Chapter One covers the introduction containing background to the study, statement of the problem, objectives, research questions, delimitations, limitations, definition of terms, importance of the study, and organization of text.

Chapter Two covers a review of relevant literature related to the topic. These are views of various authors in connection with kiln and kiln construction. Areas considered include history and development of kiln, types of kilns, types of fuel kilns (oil kilns, electric kilns, and gas kiln), Design and Construction, Methods of Kiln Construction, Heat Retention in kilns, Clay, Clay Bodies, Physical Properties of Clay, Mfensi Clay, Low-density and Brick.

Chapter Three deals with the research methodology in relation to the study. It includes the research design, library research, population, data collection instruments, primary and secondary data, data collection procedure, It also deals with the identification, observation, description of the experiments conducted to determine the right body composition that is best for the gas kiln to attain results.

In **Chapter four**, the results were assembled, discussed, analyzed and presented.

Chapter five dealt with the summary of the contents of the chapters, findings, conclusions and recommendations.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

Kilns are facilities used to house heat for eventual conversion of green clay ware into hard stone-like ware. Kilns go back to the earliest time in our civilization. Originally they were hearths or pits in the ground where pottery was placed among hot burning embers stacked up layer upon layer until the piece hardened. After several years, clay bricks became the perfect material to use when making a kiln because they can withstand the very high temperature used to fire the pottery and clay sculptures housed inside the kiln. Clay bricks have such wide applicability; they offer tremendous livelihood potential for rural communities, and business opportunities for industry. Although the advantages of clay bricks are well known, its wider utilization is hampered by lack of knowledge by most users in the developing world, and this to a large extent has affected teaching and learning in most Senior High Schools offering pottery and ceramics. Most schools do not have kilns to fire the clay works produced by students and most teachers also do not have the knowledge to compose clay bodies suitable for kiln construction.

Kilns are structures designed and constructed to house heat that may originate through the combustion of fuel or by the result of electrical resistance of an electrical element. They are usually built with materials of earth origin that are resistant to heat and will behave as insulators impeding heat transfer through the kiln wall by conduction. The kiln as a facility used in ceramics has undergone immense development and this has been reviewed in this literature related to this study.

2.1 History and Development of Kilns

Kilns, according to Rhodes (1968, 3) were one of man's earliest tools, the primitive form of which dates back to at least 8000 BC. Although the exact styles of kilns used in prehistoric times were not known, the earliest kilns, according to Rhodes were little more than bonfires. Although this assertion is believed to date back 8000 BC, some pottery villages and communities like Pankrono in Ashanti still practice this method of firing pottery. Most writers including Korankye and Oteng (2008, 45) are of the view that the method of firing clay objects to make them hard and impervious to water was discovered accidentally. From such discovery, Rhodes says it would be a small step to a more controlled management of the fire to gain concentrated heat applied to objects fashioned in clay. Rhodes (1968) explains that, the early developmental stages of the bonfire system of firing include the introduction and improvement of the pit firing, for heat retention and effective heat circulation. This innovation was well accepted by the eastern countries like Japan, China and Korea in the Far East and is noted for furthering the developments of kilns.

In a presentation, Awadzi (2002) opined that, the bonfire method of firing clay ware is the oldest means used by traditional potters in Ghana and other parts of Africa. He further explained that traditional pottery products of Ghana are generally fired by this method. It is most likely that the popularity of bonfire firing may be due to the little or no investment made to ensure a complete firing cycle. In spite of these seemingly obvious advantages, the bonfire kilns hardly fire beyond the temperature range of 700ºC-900ºC. This process of firing clay products does not make room for the conservation of heat, the energy used for the process, because the bonfire easily permits heat to escape without hindrance.

Kwakume a lecturer at the Ceramic Department of the College of Art and Social Sciences, KNUST said great advances were made in Europe during the period of the great revolution in the 1800s and industries in Europe used efficient kilns for ceramic production using coal as fuel for firing the kilns. These industrial attainments he explained most probably contributed to the setting up of parameters for kiln construction in modern times. (personal communication 2010).

2.2 Types of kilns

Kilns can be classified into two types namely intermittent and continuous kilns. Jones (1972) says that these classifications are based on their design specifications. He also says that intermittent kilns are described as periodic, and the continuous as tunnel kilns. In Ghana where pottery and ceramics is studied as an academic program, Intermittent Kilns are used and are fired by gas, diesel, or by electricity. In comparison, Amoah says the Periodic Kilns are the more flexible type since its time-temperature cycle can be tailored to a wide variety of ceramic products (personal communication, 2010). This means, the Periodic Kiln is more suited for the needs of potters and schools. The Continuous Kilns are therefore suitable for industry. The statement by Amoah makes the adoption of the Periodic Kiln more suitable for this study. Amoah further explained that, Periodic Kilns are less expensive and more cost effective. Other strong points in favour of the periodic kiln include its flexibility, which is lacking in tunnel kilns. Considering that the periodic kiln is relatively smaller in size, its construction and installation times are much shorter than that of tunnel kilns. Periodic kilns have the added advantage of occupying less floor space and have the capacity of being put to full use if need be. These advantages of the periodic kiln, `makes it the most suitable for schools of which the targeted beneficiary is included.

Kwakume, said in the design and construction of a kiln, the goal is to house heat energy put into the kiln and to use it for heating clay ware to the point of maturity. To achieve this, principal consideration must be given to the type of material that will be adopted to construct the walls of the kiln. The walls of the kiln must be of a material that has a poor thermal conductivity and has the capacity to retain heat energy when used for construction (personal communication, 2010).

Rhodes (1968) contends that low-density bricks used for the construction of kilns, fire places or fire boxes help to conserve heat because they have poor conductivity for heat. Kwakume, opined that, the heat retention properties of bricks for constructing hearths, furnaces and kilns is improved when combustible material like sawdust is added to the clay to form a body. This body is then used for making bricks which are fired and used for the construction of the hearth (Personal communication, 2010). Kwakume explained that, the combustible material burns off during firing rendering the brick porous and reducing the density of the brick. The use of this low-density bricks results in the reduction in the amount of fuel used for firing hearths and furnaces. It is therefore necessary to adopt this technology into the design and construction of the kiln and any other structure that will require heat retention as an essential property.

2 .3 Types of Fuel Kilns

Several brands of kilns are obtainable for use in ceramics. The type of kiln is known by the kind of fuel used to fire it. These comprise oil, electricity, wood and liquefied petroleum gas.

Oil is the least type of fuel used in firing ceramics. This may be due to several reasons which are more of disadvantages than advantages. Rhodes, (1968) perceived that firing with oil presents some teething troubles and requires more apparatus than other fuels. Firing with oil kiln, he explained, requires the use of oil burner, which operates on the drip-style, an instinctively multifaceted type, which involves the use of air under pressure or both air and oil under pressure. These facilities Rhodes says are always available on the market. In this, the basic underlining principle is volatilizing of oil on hot surface.

Plate 2.1: Oil fired Kiln (Source: KNUST Ceramic Section).

2.4 Electric kiln

Among all the kilns, the electric kiln is a modern development or advancement in the technology of kilns. The kilns get heated when electric current is run through resistance elements aligned inside the kiln. This generates what is known as radiant heat as the electrical current runs through. The mode of heat transfer is by radiation, hence the term radiant heat.

Plate 2.2: Electric kiln (Source: KNUST Ceramic Section).

Gas kiln

The most common kiln design utilized by contemporary potters is the natural gas updraft kiln. The use of liquefied petroleum gas (LPG) has become popular in Ghana for both domestic and industrial usage. This particular kiln also makes use of a gas burner with an industrial valve, which under control determines the quantity of gas that is released in a particular set time for combustion in the kiln. The combustion of fuel makes it necessary for an outlet for exhaust gases to escape and the chimney is an important part of the kilns that operates conventionally.

Plate 2.3: Gas kiln (Source: KNUST SHS).

Fuelling of kilns for combustion is not as important as the kilns' ability to house and retain heat for firing of works or wares that it has been designed to fire. This property of the kiln has been looked at by so many researchers such as Frederick Olsen, Bernard Leach among others and several methods of composing kiln constructional materials to have refractory and heat retention properties has been documented as several alternatives in technology of kilns. By the principle of thermodynamics, energy is transferred by conduction, convection and by radiation. In the treatment of heat retention and heat transfer in kilns, Rhodes (1968) affirmed that all three mechanisms by which heat is transferred from one substance to another have important applications in kiln design. The rate of conduction through the walls of the kiln governs the rate of heat loss, and hence the ability of the kiln to serve as a reservoir of heat.

From the above, it is evident that poor conductivity of the materials for the construction of the kiln has become paramount in the design and construction of kilns irrespective of material source. For this purpose, soft or insulating fire brick are useful in creating an effective house for heat retention in kiln construction (Rhodes, 1968). The effectiveness of the material is due to the presence of multitude of air cells which forms an effective heat barrier in the constructed brick. Steiner said clay insulating bricks can be made from refractory fireclays and kaolins. The clay is mixed into a heavy slip into which air bubbles are induced by chemical means. The entrapped air pockets make a light, porous brick, with high insulating properties and if well composed excellent resistance to heat (Steiner Rudolf, personal communication, August2010).

Olsen (2001) said a kiln constructed entirely of hard firebrick will consume a great deal of fuel, since the bricks absorb and conduct a considerable amount of heat out of the kiln. This affirms the fact that low-density bricks are a better option when it comes to material identification and selection for kiln construction.

2.6 Design and construction

All kilns operate through the release of heat-energy, and this must be achieved by the combustion of fuel with electric kilns being exceptions. Rhodes (1977) says that except for the problem of supporting the elements, there is no great construction difficulty involved in building an electric kiln. He further explained that, a kiln is a box built with refractory material to house heat directed into it for the firing of ceramic wares. It is obvious that with the present environmental problem of global warming and pollution, it has become necessary for environmentally friendly materials and fuels most appropriate for schools and institutions to be adopted for design and construction of kilns. In this regard, firewood kilns are considered inappropriate because the main fuel is fire wood.

2.7 Methods of Kiln Construction

The laying of bricks in kiln construction is a specialized masonry skill. There are rules that must be followed to ensure a strong, monolithic structure that will function efficiently at high temperatures and be durable. Olsen (2001) says that there are three vital rules in straight-wall construction. He explained that an unsupported wall about of about 11 centimetres thick cannot be higher than 90 centimetres high. Again he affirmed that an unsupported wall of 23centimetres thick, tied by alternate header and stretcher courses, cannot be higher than 240 centimetres. Finally, he concluded by saying that an unsupported wall about 34 centimetres thick, tied by an alternate header and stretcher courses, cannot be higher than 360 centimetres.

Olsen (2001) agreed with Rhodes (1977) in saying that curved walls are found in domed, down draft and beehive kilns. The reason curved walls are used is that they are much stronger and more durable and stable than straight walls. They explain that the curve creates a wedging action, which keeps the brick from falling inward. The only limiting factor on height is the compression strength of the bottom bricks. Olsen explained that domes can be cast to attain maximum strength.

2.8 Heat retention in kilns

Rhodes (1968) said insulating bricks are very important when it comes to housing of heat energy for the firing of ceramic wares. He explained that clays are mixed into heavy slip into which air bubbles are induced by chemical means. When the material is set and dried, it is fired and then cut and shaped into sized bricks. The entrapped air pockets make a light, porous brick with high insulating properties, and this he said has excellent heat resistance properties. Steiner et al (2008) also said porous bricks with insulating properties can be produced by the introduction of combustible materials like sawdust into clay, and when dried and fired, the sawdust burns off leaving air pockets in the fired body that make the brick light and porous. This gives it poor heat conductivity properties and corresponding higher heat retention ability when used in constructing kilns and furnaces.

2.9Clay

According to Peterson and Peterson (2003:131) ‘‘clay have been continuously forming for millions of years as alteration products from originally igneous rocks such as granite. Physical and chemical actions of wind, rain erosion, and gases cause the continuous decomposition of rock into clay’’. They argue that as long as the earth exists, clay is being formed. And chemically it is a hydrous of aluminium silicate with the formula $Al_2O_3.2SiO_2.2H_2O$. Chappell (1979), substantiates it more scientifically that, it is a hydrous silicate of alumina, that is to say, a compound of alumina and silica chemically combined with water. A theoretical formula of this substance reads $Al_2O_3.2SiO_2.2H_2O$.

Korankye and Oteng (2008) agreed with Chappell (1979) in saying that, clay is an earthy material substance, composed of a hydrous silicate of alumina which becomes plastic when wet, hard and rock-like when fired. Rhodes (1957) also says that clay is a temperamental material and it is abundant and cheap, easily acquired and prepared. Norton (1956) says clay is made up of tiny crystals, many of them so small that they cannot be seen under the highest power of an ordinary microscope. He further opined that clay is a secondary product in the earth and that it results from the decomposition by weathering of older rocks of the feldspar type. Korankye and Oteng (2008) further agreed with Norton (1956), in saying that clay is a product of geologic weathering of the surface of the earth. It is an end product of the weathering of rocks, the principal being feldspar. In handling the meaning and scope of ceramics, Korankye and Oteng (2008) said some ceramic products are useful in construction of bricks, and some clay are designed and composed to withstand very high temperature and these they described as insulating bricks under refractories.

2.10 Clay bodies

The adoption and composition of earth materials to attain a specific property in clay is termed Clay Body Composition. This is done in most cases to adjust a base clay material to respond to particular thermal response, or to attain properties that are lacking in the base material. Rhodes (1968) concludes in defining clay body as a mixture of clay(s) or clay and other earth materials or mineral substances which are blended together to achieve a specific ceramic purpose. In this process, Kwakume (2010) said that the researcher composing the body must have adequate knowledge of the materials in the composition so that adjustments can be made in the event of disorders. This information was found to be very relevant for this study and it was the bases for the composition of the heat retention bricks for the construction of the kiln. It is quite relevant the properties of the base material be looked at in terms of its physical behaviour.

2.11 Physical properties of clay

Clay as an earth material has properties that aid in identifying it as clay and it has qualities that make it behave in peculiar way confirming it as clay suitable for specific ceramic purposes or not. Every earth material that is said to be clay is identified on the basis of its mineralogical composition. Every clay is said to be a product of geological degradation reducing feldspartic rock into an earth material called clay. According to Speight and Toki (1999), this feldspar has alkaline, silica and alumina as its main components, and these are reduced to aluminosilicates by glacial activity. After prolonged exposure to the environment, the aluminosilicates combine with the humidity of the environment and gives rise to the formation of new material call clay. Home (1953), also affirmed that this new material called clay differs from place to place due to the differences in the minerals present during the formation.

Home (1953) however, said that almost all clays apart from kaolin have some level of plasticity, a physical property that allows for modelling and forming with the clay. There are factors that influence the plasticity of every clay. The particle size of the clay according to Rhodes (1968) is a determining factor of the plasticity of the clay. Finer particle size contributes to high plasticity whereas coarser particles reduce plasticity. Speight and Toki (1999) explained that clays differ in their degree of plasticity. Some are so sticky they are almost impossible to shape. Rhodes (1977) mentioned colour as another physical property of clay that easily affects the clay's thermal responses. He said that there are minerals that show their colour only when the clay mineral has been exposed to heat. He explained these as metallic oxides that in some cases act as fluxes reducing the maturing temperature of the clay.

The plasticity of clay was found to be of critical importance in this study because it is this property that aids the binding of materials, especially in the case where non-plastic materials are involved. The property of plasticity is of primary importance where and when forming is concerned. Although the plasticity of the base material can be reduced by the introduction of non-plastic material, proper control measures aid in arriving at an expected end. Almost all the clays available in the pottery villages in Ashanti are comparatively plastic and it is against this that the Mfensi clay is being considered for this study. Other factors that were considered for the choice, was location and accessibility.

2.12Mfensi clay

Mfensi clay has been used by local potters over several years. This clay can withstand high temperatures. It is thus suitable for the production of some medium range refractory materials and has a shrinkage percentage of 11. Thus, Mfensi clay is not difficult to form and does not easily crack after forming. According to Nsiah (2007), it is advisable to add some shamot (grog) or sand to reduce shrinkage of Mfensi clay products. Moreover, the clay experiences substantial mass change after firing, meaning that it contained appreciable amount of organic material, which also contributed to the formation of colloidal gels hence its plasticity. Mfensi clay is, thus, suitable for earthenware, bricks and tiles. A mixture of Mfensi clay and any other clay, with adequate plasticity index, would result in a material of varying properties useful for many ceramic products. In a presentation on clays in Ashanti, Obeng and Atiemo (2006, 31) concluded that clays in Ashanti are suitable for burnt bricks production when fired to a temperature of 1050°C. They said bricks produced at this temperature are better because they have better tensile and compressive strength. This analysis of the Mfensi clay gives a report that declares it suitable in addressing the problem of composing heat retention bodies suitable for kiln construction.

From the above studies made by the various writers on the available technologies, there is ample information on the development of heat retention bodies from locally available clays and other complementary raw materials for the composition of low or poor conducting bodies to be used as heat retention materials for kiln construction.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter discusses the processes of collecting data necessary for the study, including the research design, library research, primary and secondary sources of data, population for the study, sampling design, data collection instruments, and data collection procedures. The tools and materials used in the study are also described. The chapter chronologically dealt with the general procedures in executing the project.

3.1 Research Design

The qualitative research paradigm was used in this study. In this, the descriptive and experimental methods of research were adopted to collect data for the study. The descriptive research method was used to describe the entire project and the experimental research method was used for the formulation of the low-density body using Mfensi clay and saw dust, and the designing and construction of the kiln. Pre-experimental design was chosen for this project because it employs a single group and although it has a disadvantage of lower validity; it is very practical and sets the stage for further research. For the purpose of this study, qualitative research method was adopted because it provided a systematic approach in unfolding the facts to determine the technique for kiln construction.

3.2 Qualitative Research

Qualitative research answers questions about the complex nature of phenomena, often with the purpose of describing and understanding the phenomena from the participant point of view (Leedy & Ormond, 2005).Shank (2002, 5) also defines qualitative research as “a form of systematic empirical inquiry into meaning.”Denzin and Lincoln (2000, 3) agree that qualitative research involves an *interpretive and naturalistic* approach. “This means that qualitative researchers study things in their natural settings, attempting to make sense of, or to interpret, phenomena in terms of the meanings people bring to them.”A Descriptive and Experimental method of qualitative method was selected to provide a systematic approach in generating new technique in the formulation of body for the kiln construction.

3.2.1 Experimental Research

An attempt was made by the researcher to maintain control over all factors that may affect the result of an experiment. In doing this, the researcher attempts to determine or predict what may occur (Key, 1997).Experimental research employs different treatments and establishes their effects in the study. The outcome leads to clear interpretations of effects and findings. The general procedure is the description of the step by step approach by which the entire project was done.

3.2.2 Descriptive Research

Descriptive research on the other hand, describes data and characteristics about the population or phenomenon being studied. The idea of selecting descriptive research method was that, the procedures employed for carrying out the experiment needed to be described chronologically, to produce a very clear and detailed account of all occurrences pertaining to the project. Most quantitative research falls into two areas: studies that describe events and studies aimed at discovering inferences or causal relationships. Descriptive studies are aimed at finding out "what is," so observational and survey methods are frequently used to collect descriptive data (Borg & Gall, 1996). Descriptive research involves gathering data that describe events and then organizes, tabulates, depicts, and describes the data collection.

3.3 Library Research

Library research is the basis by which a researcher greatly develops the writing of a scholarly thesis. It provided majority of the secondary data needed. The libraries that provided secondary data relevant to the research include:

The KNUST main library, the College of Art Library, Department of Art Education Library, Faculty of Engineering Library and the Faculty of Science Library, all in the Kwame Nkrumah University of Science and Technology. Others are British Council Library and Library of the Building and Road Research Institute of the Centre for Scientific and Industrial Research at Fumesua in Kumasi. Books, publications, periodicals, magazines were the sources from which secondary data were collected.

3.4 Population for the Study

According to Fraenkel and Wallen (1996), a population is the group of interest to the researcher, the group to whom the researcher would like to generalize the results of the study. Leedy and Ormrod (2005), also state that qualitative researchers draw their data from many sources – not only from a variety of people, but perhaps also from objects, textual materials, and audio visual and electronic records. The researcher therefore identified the following as the population pertinent to the study:

3.4.1: Target Population

In this study the researcher targeted the senior officers of institutions and establishments (Managers of clay processing factories, teachers and lecturers of clay art, technicians of clay processing industries, research institutions and artisans working with clay within Kumasi.

3.4.2: Accessible Population

A total of 12 people were interviewed on kiln construction and the methods they adopted in the production of suitable bodies for kiln construction. They were made up of five (4) Senior officers of institutions and establishments (Managers of clay processing factories, teachers and lecturers of clay art), two (2) Technicians of clay processing industries and research institutions and six (6) artisans working in clay.

In this some agreed on initial designing of the kiln, followed by composition of desirable heat retention body for the kiln (low-density body) from available local raw materials, and the formulation of a suitable kiln mortar for the construction of the kiln.

Suggestions on the mortar compositions recommended that different materials of the clay origin can be adopted provided they are made up of plastics, non-plastics and some high temperature materials like local kaolin or builder's sand. They agreed that deflocculation was very necessary to ensure the proper functioning of the mortar as leveller and a binding paste.

3.4.3 Sampling Techniques

Sample in the context of this study is a portion, piece or segment that is representative of a whole population. Leedy and Ormrod (2005) have the view that, the particular entities a researcher selects is what is termed the sample, whereas the process of the selection is the sampling. After identifying the population, purposive sampling was employed to gather the information because Leedy and Ormrod (2005) continue to explain that, in purposive sampling, people or other units are chosen, as the name implies, for a particular purpose. The researcher therefore relied on purposive sampling technique to conduct the experiment.

3.4.4 Characteristics for the Population of Study

Population concept is fundamental to both descriptive and analytical research. For this study the researcher considers a population as a group of persons having information on kilns and kiln construction. Within the context, people working with kilns, teaching about kilns and who construct kilns are considered to constitute the population for this study.

A total potential population for this research project was sixteen (16), made up of senior officers of institutions and establishments (Managers of clay processing factories, teachers and lecturers of clay art), Technicians of clay processing industries and research institutions and artisans working in clay.

3.4.5 Justification of Sample Selected

Based upon the above information, the researcher considered a sample of 12 (75%) to be a representation of the total population. The 12 became accessible population (respondents).

3.5 Data Collection Instruments

In conducting a qualitative research a researcher uses either a single instrument or a triangulation means of collecting data in most cases. Leedy and Ormrod (2005) are of the view that researchers normally make use of multiple forms of data in any single study through observation, interview, objects, written documents, audiovisual materials, electronic documents (e-mail, websites). In this study however, observation and interview were the main instruments employed.

3.5.1 The Observation

Observation in philosophical terms is the process of filtering sensory information through the thought process. Input is received by hearing, sight, smell, taste, or touch and then analysed through either rational or irrational thought. With the passage of time, impressions stored in the consciousness about many related observations, together with the resulting relationships and consequences, permit the individual to build or construct about the moral implications of behaviour.

The defining characteristic of observation is that it involves drawing conclusions, as well as building personal views about how to handle similar situations in the future, rather than simply registering that something has happened. However, observation does not necessarily imply drawing conclusions and building personal views instead of the accumulation of knowledge. The researchers observed and studied the different constructional methods and brick making processes. This helped the researcher to accumulate ample knowledge about Kilns.

3.5.2 The Interview

Interview is defined as the questioning of a person (or a conversation in which information is elicited). Frey and Oishi (1995, 10) define it as a purposeful conversation in which one person asks prepared questions (interviewer) and another answers them (respondent). This is done to gain information on a particular topic or a particular area to be researched. The researcher interviewed a group of clay artisans at the Kumasi Centre National Culture, Lectures and teachers of ceramics and technicians at Building and Road Research Institute were also interview for their general view about bricks for kiln construction. The researcher used unstructured interview in collecting data needed for the study from respondents.

Unstructured or open-ended interviews are defined by Nichols (1991, 131) ‘‘as an informal interview, not structured by a standard list of questions’’. For convenience, the researcher chose to use the unstructured interviews in order give room for respondents to express themselves and feel free of tension. By this, other information was tapped unaware. In the unstructured interviews, the researcher just had normal conversation with respondents and jotted down summarized information deduced off the scene of conversation. Because it was not made formal, the respondents talked freely and contributed with ease. This method was used when talking to people with little or no education background because they get scared with book and pen. Interviews were conducted in English and Twi and later transcribed the Twi into English for analysis.

3.6 Types of Data

3.6.1 Primary Data:

This was gathered from the activities performed during the course of the experiment to identify the general constructional methods adopted for kilns and the compositions and formulations of bodies suitable for low-density heat retention bricks and mortars. This was by critical observation made by the researcher. The data comprise all the interviews, discussions, direct personal observation, sketches and the personal communications.

3.6.2Secondary Data:

The secondary data comprised the entire literary materials sought, cited and used from books, articles and published unpublished thesis, internet, journals, magazines and others that were related to this study.

3.7 Data Collection Procedure

Having collected the secondary data from documentary sources (books, publications, periodicals, charts, brochures and thesis) and reviewed the related literature, the researcher built a framework of the study and based upon that, she identified and established the techniques applicable to the study and related requisite tools and materials.

The researcher visited the various sites to see the respondents and introduced herself, the proposed project and the information needed to accomplish the work. The researcher then officially booked suitable appointment dates with the respondent. The researcher adopted the face-to-face unstructured interview to collect data.

3.8 Data Analysis Plan

After getting the needed information, the researcher then proceeded by preparing the clay body to experiment the suitability of the various body composition techniques for kiln construction. The result was then analyzed to derive the findings and conclusions, and recommendations were finally drawn.

3.9 General Procedure in Executing the Work

3.9.1 Design and Production Stages

Introduction

The method adopted for the construction of the kiln is basic. It is made simple to enable a lay person read, understand and follow the procedures in the construction of a similar kiln.

For firing of ceramic works, most kilns are made from low-density refractory bricks designed and produced to retain heat required in a kiln to bring green ware to the point of maturity.

This particular kiln adopts local earthenware clay and sawdust in a deflocculated system to arrive at a product that is porous, low-density, has considerable heat retention properties, suitable for the construction of kilns that can retain heat to temperatures exceeding 1200°C.

In designing and constructing the kiln, the researcher considered the entire project in stages; the designing stage, the low-density bricks formulation and production, the formulation of the kiln mortar that was used for the laying of the low-density bricks, and the metal frame to encase the bricks to form the kiln.

a. Design

According to David and Stephen (2008) design indeed means to plan, to organize. They say design is inherent in the full range of art disciplines. Virtually the entire realm of two and three-dimensional human production involves design, whether consciously applied, well executed, or ill considered. Inferring from the explanation above, design necessitates planning to produce or achieve a purpose, and it forms the foundation of every work and provides a summary of a plan serving as a template for a work to be executed.

The design of the brick kiln was started by making preliminary sketches. One of the sketches was chosen and with the aid of CorelDraw® and Rhinoceros® software, the kiln was designed two dimensionally and three dimensionally respectively.

b. Concept of design

Simple arrangement of forms of design elements is very necessary for designing and production of any art work. It is deemed expedient to eliminate unnecessary and complicated design that causes a lot of problems and hence tends to mar the progress of the processes of making a unique piece of work.

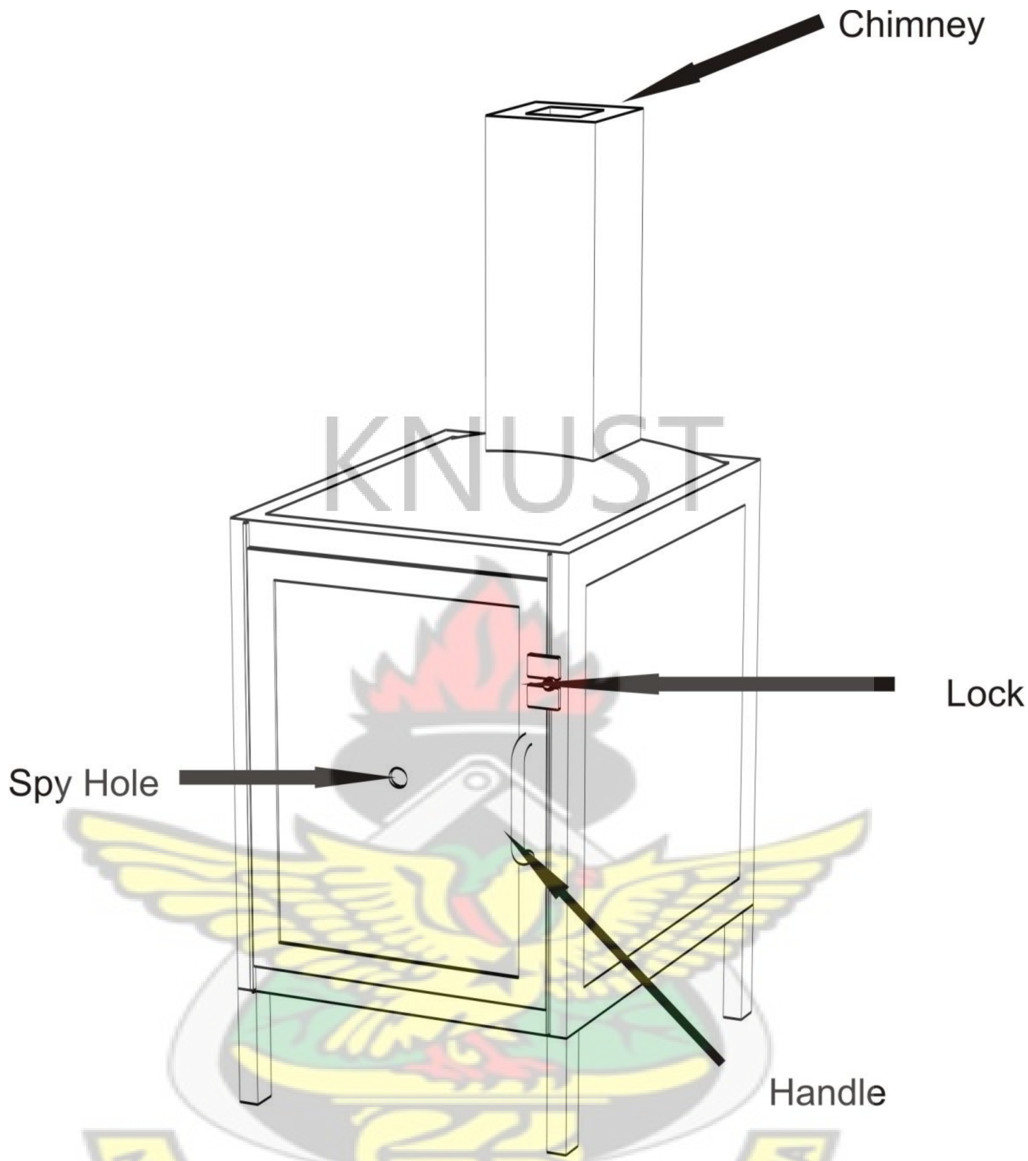

Figure 3.1: CorelDraw view of kiln

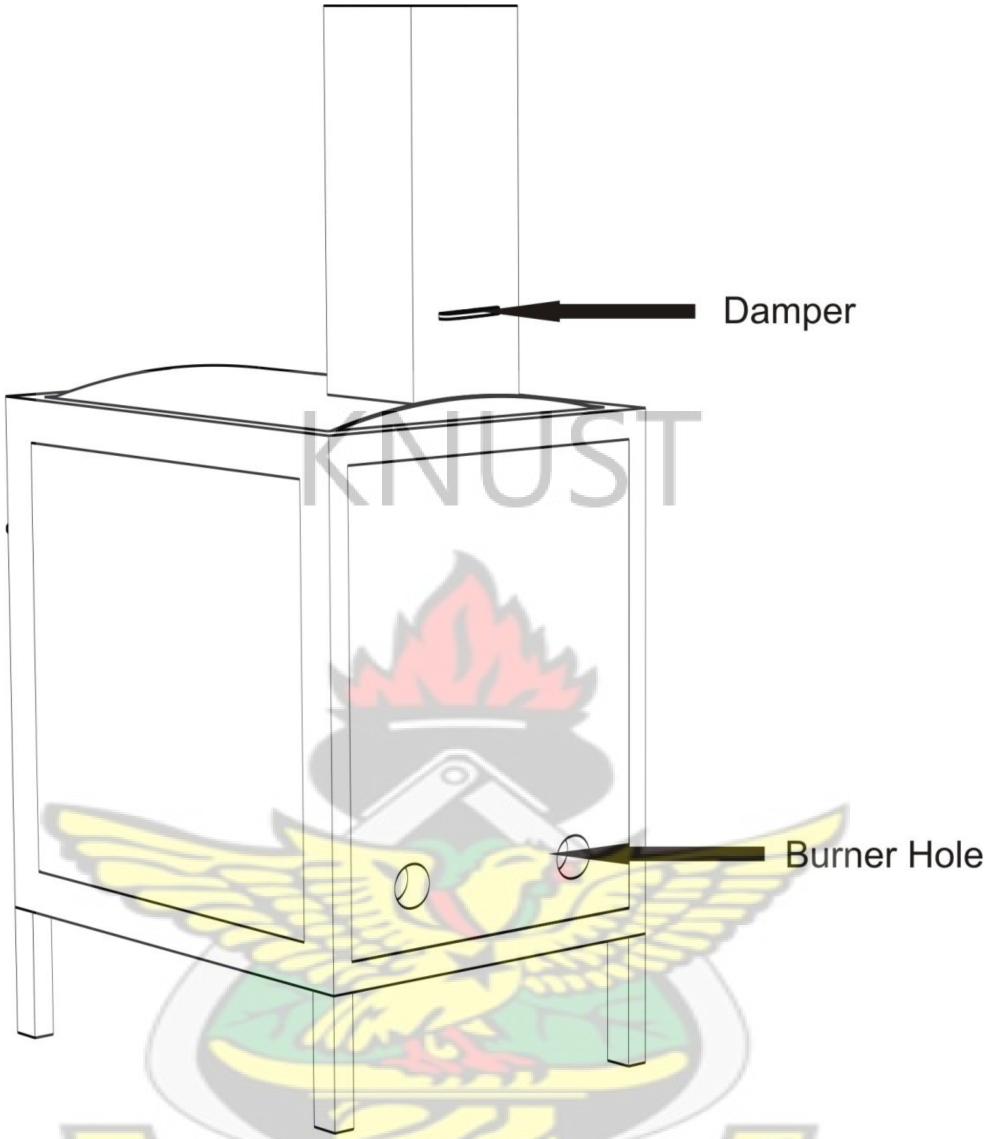

Figure 3.2: Labelled back view of kiln in CorelDraw

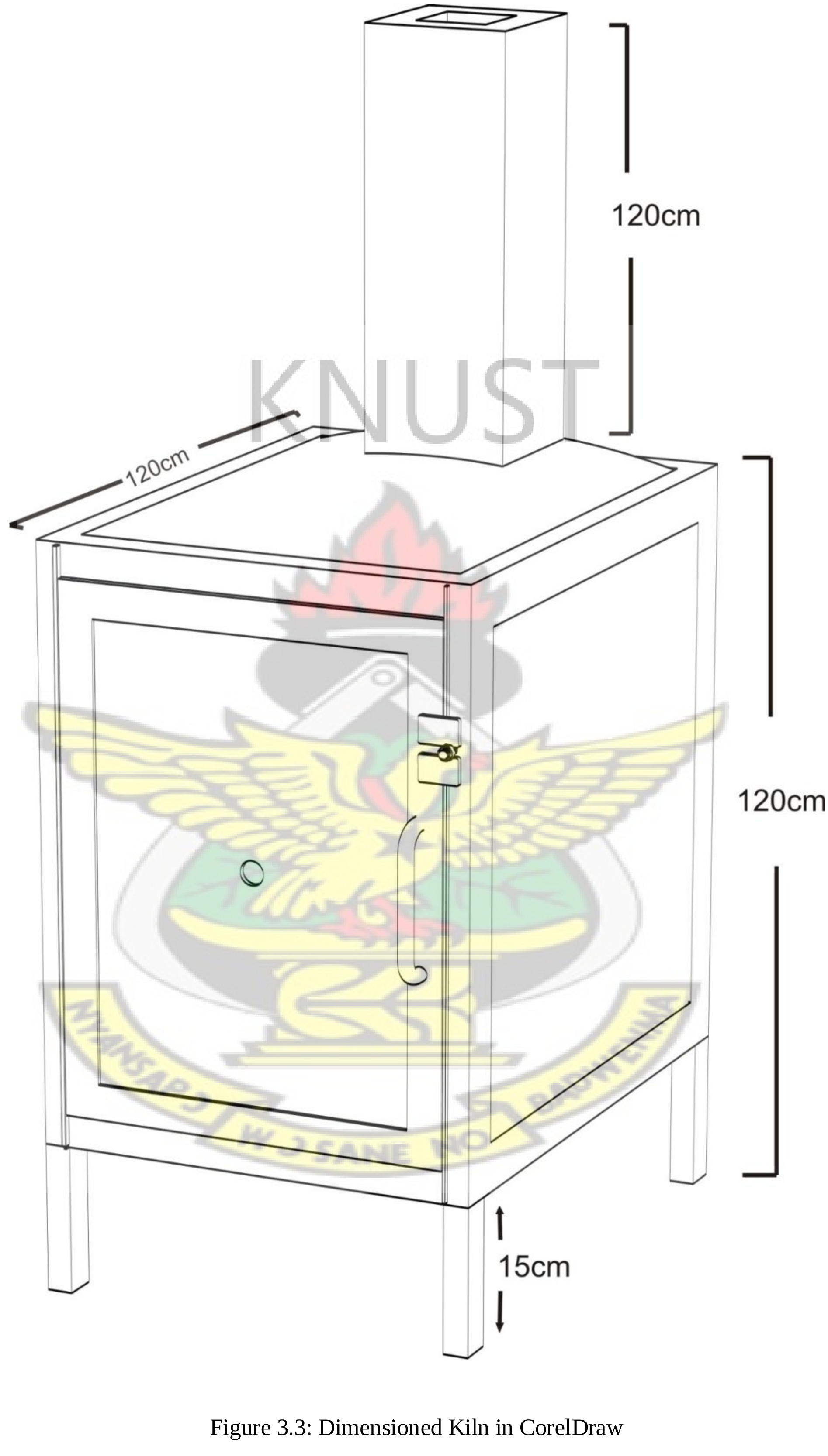

Figure 3.3: Dimensioned Kiln in CorelDraw

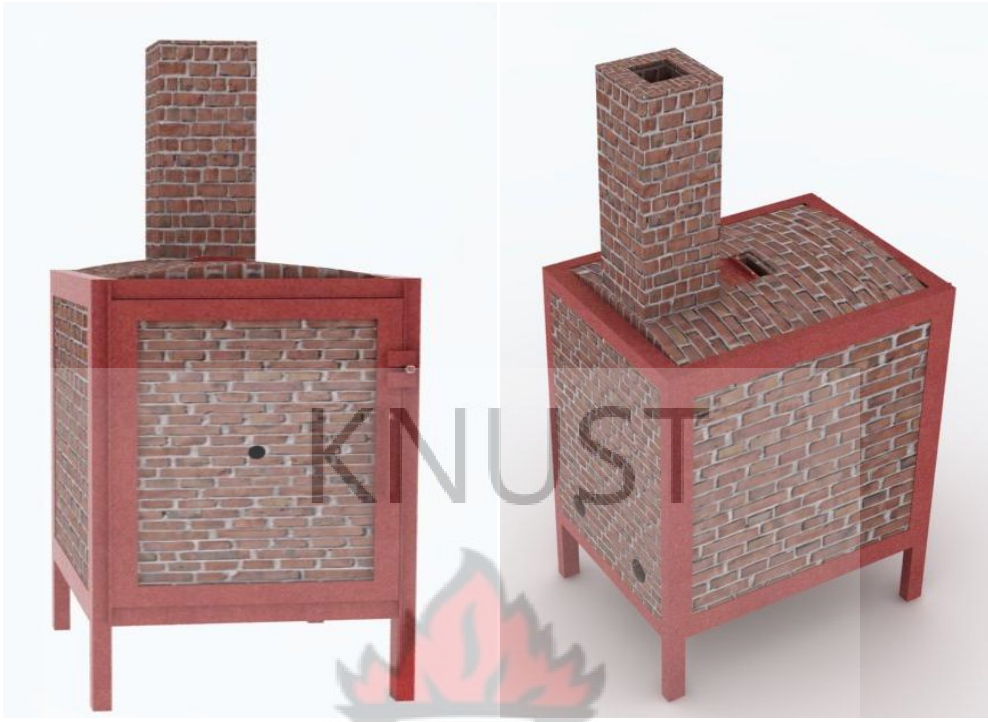
Figure 3.4 The kiln in Rhinoceros

3.9.2: Tools, Equipment and Materials

In this study, materials, tools and equipment used have been described. These are any hand or machine-operated devices employed in engineering, manufacturing, woodworking, and metal work to shape metal or wood products or parts.

Commonly used tools for this project include hand trowel, hack saw, sledge hammer, metal workers' chisel, metal workers' bench, vice and anvil. Equipment used includes Welding machine, blunger, pug mill, jaw crasher, ball mill, test kiln, fire wood kiln, brick making mold and weighing scale.

Hacksaw:

Hacksaw is a tool with a metal blade designed to cut wood, plastic, metal, and other materials (plate 3.1). The blade of a saw has small, sharp metal teeth along the cutting edge. The teeth are slightly bent alternately to either side of the blade; this makes the kerfs (groove) cut by the saw slightly wider than the blade itself, preventing the saw blade from binding against the material being cut. This particular tool was used in cutting the angle iron used for the construction of the frame work of the kiln.

Plate 3.1 Hacksaw

Hand trowel:

Hand trowel is a tool with a metal blade and a wooden handle designed for masonry work in building construction or in kiln construction (plate 3.2).It is used in applying mortar to brick and dressing the surface of brick work. It was the main tool used in the laying of the low-density bricks during construction of the kiln.

Plate 3.2 Hand trowel

Hammer:

This is a hand tool used for driving nails into objects. It is also used for beating metal into form and shape. It is made up of a metal head and a wooden handle normally beach wood. It was used with the metal workers chisel for cutting metals where the hacksaw was unable to cut (plate 3.3).

Plate 3.3 Hammer

Metal workers cold chisel:

This is another hand tool used for cutting metal plates (plate 3.4). Chisels are made of tool steel and are hardened and tempered. Depending on the type of chisel, they are made with a cutting edge angle of forty five or sixty degrees.

Plate 3.4 Metal workers cold chisel

Anvil:

This is a solid metal cast piece made in wrought iron. It has the shape of an abstract bird with a beak, a tail and a hardened cutting table (plate 3.5). It is on this table that both cold and hot metals are worked on. This was very useful when cutting and fabrication of the armature of the kiln was started.

Plate 3.5Anvil

Try square:

This is a hand tool made up of a metal blade and metal handle (plate 3.6). It is used for checking squareness of materials and objects. It was the main tool that aided the marking out of constructional lines before cutting and welding was done.

Plate 3.6 Try square

Shears:

This is cutting instrument with two blades, the edges of which slide past each other. A common fulcrum in the form of a screw or a pin attaches the blades, and they operate simultaneously by lever action when the handle is pushed together (plate 3.7). This was used in the cutting of very broad metal sheets.

Plate 3.7 Shears

Weighing scale:

This was the equipment used for weighing clay and saw dust samples for composing low-density bricks for the construction of the kiln (plate 3.8). It was used for finding out the mass of fired low-density bricks for the calculation of their densities and the determination of their porosity percentages.

Plate 3.8 Weighing scale

Jaw crusher:

This equipment was used to reduce large dried clay lumps into smaller chippings for milling in the milling machine (plate 3.9). It is also used for crushing very hard earth material like feldspar tic rocks.

Plate 3.9 Jaw crusher

Milling machine:

To reduce chippings of feldspar, clay and other earth minerals into finer particle size this equipment was used (plate 3.10). It is the main equipment that was used for processing the low-density clay body.

Plate 3.10 Milling machine

Ball mill:

With the aid of pebbles of porcelain (porcelain balls) this equipment reduces materials processed from the milling machine into fine dust (plate 3.11).It was used in processing all the experimental bodies composed for testing and selection for use in the project.

Plate 3.11 Ball mill

Pug mill:

This equipment is used for effective mixing of clay body to form a sticky mass in the right consistency (plate 3.12). It was used for mixing the composition that was chosen for the project.

Plate 3.12 Pug mill

Wooden brick making mould:

This wooden frame was used for moulding several samples of low-density bricks of different composition for testing and selection for use in the project (plate 3.13).

Plate 3.13 Wooden brick making mould

Electric test kiln:

This is a box of low-density refractory bricks lined with heat generating elements with regulators to control the heating of its chamber (plate 3.14). This equipment was used to fire all test samples that were made. It has the capacity to fire up to 1700 degrees Celsius.

Plate 3.14 Electric test kiln at ceramics section KNUST.

Drilling machine:

This machine is used for making holes through metals and other materials during constructions (plate 3.15).

Plate 3.15 Electric drilling machine

Firewood kiln:

This is a wood fuel kiln used for firing pottery wares (plate 3.16). This kiln was used for firing of the low-density bricks used in the construction of the kiln.

Plate 3.16 Firewood kiln

Electric welding machine:

This equipment is used for electric arc welding (plate 3.17). An arc forms when current flows through two electrodes that is separated and gives off light and heat. A protective viewing plate allows the welder to view the welding process without fear of damage to the eyes. This machine was used in joining all the metal parts of the kiln frame.

Plate 3.17 Electric Welding machine

Saw dust:

This material was mixed with the Mfensi clay in different proportions to experiment for the production of low-density bricks (plate 3.18). It was the main component of the clay body used for the production of low-density bricks for construction of the kiln.

Plate 3.18Saw dust

Clay from Mfensi:

This clay was mined at Mfensi (plate 3.19), a village about thirty five to forty kilometres on the Kumasi - Sunyani road. It fires red, an evidence of the presence of significant amount of iron oxide. It has maturing temperature between thousand degrees Celsius and thousand one hundred and fifty degrees Celsius. It is used mostly by the locals of the Mfensi village for producing water cooler, grinding pots and burnt bricks for housing. Mfensi clay, according to Obeng and Atiemo (2006:31) have the following chemical composition SiO_2= 69.8%, Al_2O_3=15.7%, Fe_2O_3=4.6%, CaO=0.2%, MgO=0.1, SO_3=0.02 and Loss on ignition=5.3.

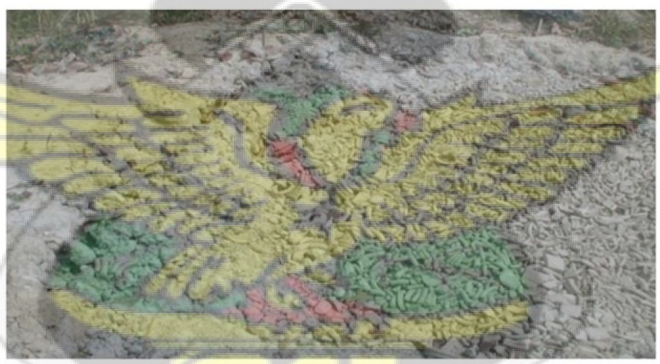

Plate 3.19 Clay from Mfensi

Mild steel plate:

This was used for the fabrication of the base of the frame (plate 3.20). This material is malleable so easily fabricated into things like car bodies, water containers and gates. It allows welding and this property is essential for the project.

Plate 3.20 mild steel plate

Angle iron:

The angle iron was used for the construction of the frame works in the project (plate 3.21).

Plate 3.21 millimetre angle iron

Fuel wood:

These are off cuts of forest products purchased from timber concession allocated to some timber firms in Ashanti region, Ghana (plate 3.22). These were used to fuel the kiln to fire the bricks for the kiln.

Plate 3.22 Fuel wood

3.9.3 Objectives One and Two:

The first objective was to study the methods and processes in composing low-density bricks from local earthenware clay while the second objective was meant to compose low-density bricks from Mfensi clay.

a. Composing low-density bricks.

The researcher therefore considered the creation of multitude air cells in the bricks for the construction of the kiln as necessary physical properties required for the retention of heat in the kiln. To arrive at a suitable body composition for the manufacture of low-density bricks for the construction of the kiln, several experiments were conducted to arrive at the suitable composition for the clay body. The materials that were used for the experiments were Mfensiclay, saw dust, water and sodium silicate (deflocculant). In this it was expected that, the clay would form the main body component in the composition, the sawdust the second component which was a combustible material will eventually burnt off during firing to create the multitude of air cells required for retention of heat. The sodium silicate deflocculated the entire composition, reducing the quantity of water of plasticity required for binding and reducing the time for drying. The weighing scale (plate 3.8) was used to weigh the materials for experiments 1, 2, 3, 4, and 5, and were all fired at the same time in the same test kiln (plate 3.14) to the same temperature.

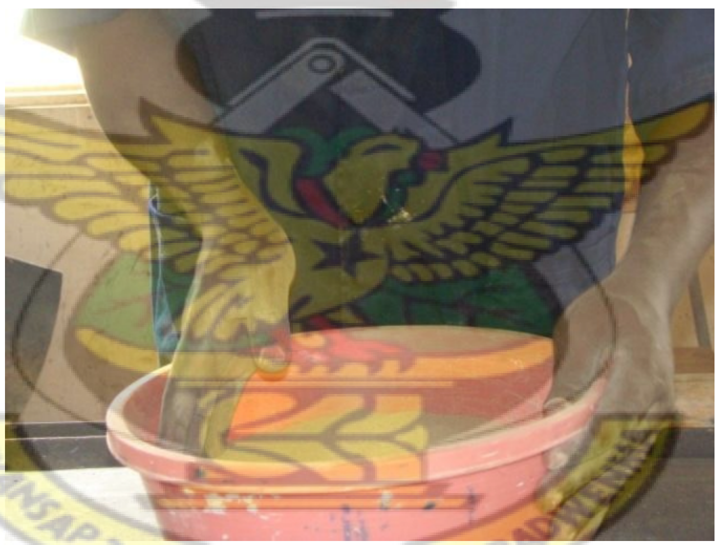

Plate 3.23 Researcher mixing body (clay and sawdust)

Plate 3.24 Researcher composing low-density body for bricks

Experiment One:

Table3.1Quantity of materials for experimental brick one

Materials	Quantity
Mfensi Clay	1000 grams
Sawdust	100 grams
water	300 grams
Sodium silicate	1 drop

This composition was ball milled in the porcelain pots for 30 minutes to ensure a homogenous mixture before the water and sodium silicate was added, mixed, cast, dried and fired. This body was fired to 1300 degrees Celsius.

Experiment Two:

Table3.2 Quantity of materials for experimental brick two

Materials	Quantity
Mfensi clay	1000 grams
Saw dust	200 grams
water	300 grams
Sodium silicate	1 drop

This composition was ball milled for 30 minutes in the porcelain pot after which the water and sodium silicate was added mixed in a plastic bowl , cast in a brick makers mould, dried and fired to 1300 degrees Celsius.

Experiment Three:

Table3.3Quantity of materials for experimental brick three

Materials	Quantity
Mfensi clay	1000 grams
Saw dust	300 grams
Water	300 grams
Sodium silicate	1 drop

In this composition, the sawdust was more than what the clay could hold. Molding into a brick was impossible.

Experiment 4:

Table3.4Quantity of materials for experimental brick four

Materials	Quantity
Mfensi clay	1000 grams
Saw dust	400 grams
Water	300 grams
Sodium silicate	1 drop

This composition could not be moulded into bricks because the sawdust was more than the clay could hold and bind. This was discovered after the composition has been ball milled and was ready for casting.

Experiment 5:

Table3.5Quantity of materials for experimental brick five

Materials	Quantity
Mfensi clay	1000 grams
Saw dust	150 grams
Water	300 grams
Sodium silicate	1 drop

This composition was ball milled in the porcelain pots (plate 3.10) for 30 minutes to ensure a homogenous mixture before the water and sodium silicate was added, mixed, cast, dried and fired. This body was fired to 1300 degrees Celsius.

Plate 3.25 Researcher moulding experimental low-density bricks

Plate 3.26 Researcher putting experimental samples in the test kiln

Test firing enabled the researcher to experience the changes that occurred in the material under manipulation after subjecting it to heat. It also revealed the extent to which the material can be subjected to thermal pressure.

In the production of the low-density bricks type selected for the project, pain was taken in weighing all the materials into the ball milling machine to ensure the production of the right quality of low-density bricks. To ensure even distribution of saw dust and clay, the ball mill was made to run for one hour, after which the composition was collected in very large containers and water and sodium silicate (deflouculant) were added and mixed together. This activity ensured the thorough mixing of the various components of the body.

The composition was thoroughly mixed with the pug mill, and was purged out in bars of 80 centimetres having diameters of 10 centimetres.

The composed body was then stored in air tight boxes lined with galvanized sheets. A one brick maker's mould, for producing bricks with sides measuring 24 x 12 x 7 centimetres was used for the production of the low-density bricks. For easy manufacturing of bricks, used engine oil was used to lubricate the mould, before the body was cast into the mould to produce bricks. The bricks were air dried under shade and fired in the firewood kiln to a temperature ranging between 1000 and 1050 degrees Celsius. In this composition, the maturing temperature of the base clay was used since all fluxes and other minerals would have come to the point of fusion, giving strength, and hardness to the composed body. In all it took three days to fire the kiln until the bricks were matured. The fired bricks were unpacked from the kiln after four days when the kiln had cooled down.

Plate 3.27 Unfired bricks produced

Plate 3.28 Fired low-density bricks

Table3.6Properties of low-density fired brick

True porosity, %	40.2
Density in g/cm3	0.897
Crushing strength in kg/sq cm.	60
Maximum service temp. in Celsius	1050
Average mass of each brick in grams.	500
Size of brick. in cm	24 x 12 x 7

3.9.4 Objective Three:

The third objective was to use the composed bricks for the construction of a gas-fired kiln. To be able to achieve that, a metal frame was fabricated to encase the bricks.

Fabrication of the frame for the kiln

To ensure that the correct measurement is used, the researcher did all measuring and cutting of materials to design specification. The material used for the frame was 50 mm angle iron.

Plate 3.29 Measuring and cutting materials to size

After cutting the materials to the specific sizes the researcher employed the services of an electric arc welder to weld the cut pieces together. The grinding machine was used for neatening up the welded joints to finish.

Plate 3.30 Welding the angle iron

Plate 3.31 The angle iron frame of the kiln under construction

Plate 3.32 The angle iron frame painted with anti rust paint

To ensure that the entire construction of the kiln is done under the correct standards required in kiln construction, technical representation of the design was made in coral draw to allow for technical criticism to be made as a major guide to the construction of the experimental kiln. In this a first angle projection of the kiln was made. This allowed for criticism and again served as a guide for the construction of the kiln.

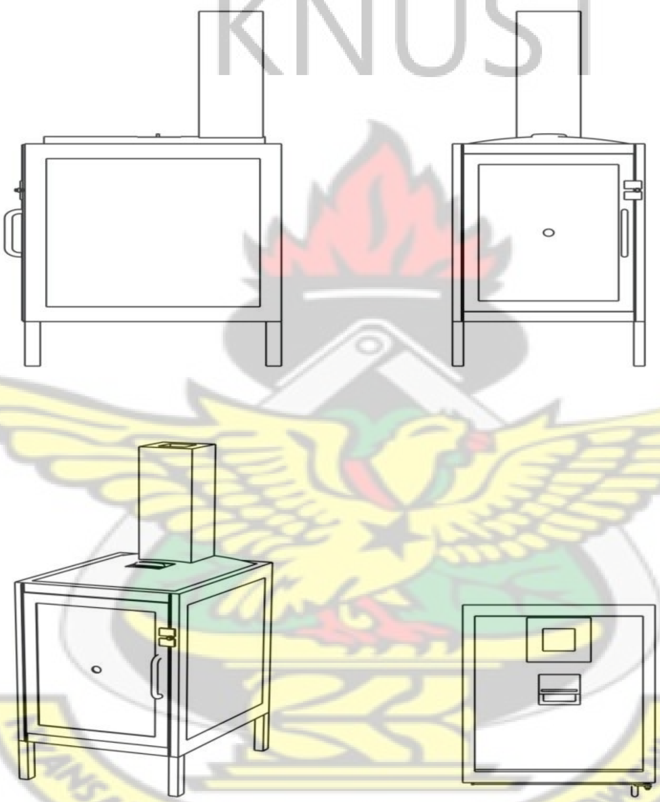

Figure 3.5 First angle projection of kiln

Construction of the kiln

The construction of the kiln started with the positioning of the constructed frame on level ground to ensure a proper take off of the constructional process. Steiner (Dec. 2010, personal communication) said that the basic elements of any ordinary structure are the floors and roof (including horizontal supporting members), columns and walls (vertical members), and bracing (diagonal members) or rigid connections used to give the structure stability.

Steiner further indicated that, with low structures, the variety of possible shapes is much greater than with taller structures. Each structural material has a particular weight-to-strength ratio, cost, and durability. As a general rule, the greater the span, the more complicated the structure becomes and the narrower the range of suitable materials. The supporting structure and exterior walls, floor, may also be made as a unified whole, much like a rectangular box with closed or open ends. These forms may be welded with an electric welding machine.

By far the most common form of structure is the skeletal frame, which consists essentially of the vertical members combined with a horizontal framing pattern. The skeleton frame most often consists of multiples of the construction. The basic elements of the metal skeleton frame are vertical columns, horizontal girders spanning the longer distance between columns, and beams spanning shorter distances. The frame is reinforced to prevent distortion and possible collapse because of uneven loads. Lateral stability is provided by connecting the beams, columns, and girders; by the support given the structure by the floors; and by diagonal bracing or rigid connections between columns, girders, and beams. To provide for greater flexibility within constructed structure, movable or easily disassembled systems may be used, the only restriction to their placement being risks and threats. This was the guiding principle under which this kiln was constructed.

Plate 3.33 The laying of the ground surface foundation

The construction of the kiln started with the spreading of the fired low-density bricks to form the base foundation protecting the ground plate from direct contact with the heat or flames of the kiln. This served as the foundation of the kiln laid in the frame work housing the kiln.

The mortar for the laying of the bricks was composed locally from raw materials available to the researcher. Rhodes (1968) explained that mortars prepared locally are as good as ready made ones, and suggested the following composition.

Table 3.7 Composition of local mortar

Available local plastic clay	15 kg
Flint or builders sand	30 kg
Sodium silicate	.05 lit.
Kaolin	55 kg

This composition was used for the construction of the kiln. The entire composition was like soft mud, almost soft enough to flow. The roles of the various parts in the composition are as follows.

Table 3.8 Composition of local mortar

Plastic clay	The main body ingredient for the composition.
Builders sand	To give strength to body after firing.
Sodium silicate	To give better dry strength to the body
kaolin	To give higher temperature adaptability

Plate 3.34 The foundation of the kiln covered with mortar

The locally composed kiln mortar was spread to cover the bricks at the base of the frame. This was part of the preparatory ground work necessary for vertical construction or laying of bricks to begin (plate 3.34).

Plate 3.35 Mixing of locally composed kiln mortar

Plate 3.36 Vertical construction of kiln wall or laying of bricks

Plate 3.37 Right Angular treatment of kiln wall building

Plate 3.38 Construction of burner hole

Plate 3.39 Internal walls of the chimney

Plate 3.40 Starting the chimney

Plate 3.41 Construction of chimney

Plate 3.42 Dome framework fixed on top of kiln wall

Plate 3.43 Constructing the armature of the dome

Plate 3.44 Constructing the dome

Plate 3.45 Dome construction.

Plate 3.46 The dome of the kiln

Plate 3.47 Starting the Kiln door

Plate 3.48 Constructing the kiln door

Plate 3.49 Completed kiln door

Plate 3.50 creating Avenue for the damper

Plate 3.51 The back of the kiln showing burner holes

Plate 3.52 The front of the kiln

Plate 3.53 Burning off the armature forming the dome

3.9.5: Objective Four:

The fourth objective was to use the constructed gas-fired kiln for the firing of ceramic wares and evaluating its effectiveness.

The kiln was subjected to test to assess its performance and viability for the purpose for which it was designed and constructed. Test firing was done using hand built ceramic forms including works produced by students of Yaa Asantewaa Girls Senior High School.

Plate 3.54 Kiln packed with green wares for test firing

The works were arranged in such away that will allow easy movement of the energy to ensure even distribution of heat for effective firing of the works. After arranging the works in the kiln, the kiln door was shut and the burner was lit and directed into the burner hole. (See plate3.55)

Initially the emission of energy was very slow and low although the gas burner is rated at160000 joules. This was to ensure the smooth removal of moisture and to raise the internal temperature of the kiln gradually to the point where the works would have been brought to point of maturity. The entire firing period took 8 hours at which the internal temperature of the kiln was about 1000ºC. The kiln was opened after 24 hours cooling time. The items fired include pots, sculptures and bricks composed of clay and sawdust. The results of the construction and the test firing was done to ensure that the overall benefit that will be derived from providing Yaa Asantewaa Girls Senior High School with a kiln for firing ceramic works is attained.

Plate 3.56 Researcher and ceramic teacher assessing fired wares/products.

CHAPTER FOUR

PRESENTATION ANDDISCUSSION OF RESULTS

4.0: Overview

This chapter discuses and presents the results of the use of Mfensi clay and saw dust as locally obtainable raw materials for the composition of low-density bricks, for use as heat retention bricks for the construction of a gas-fired kiln. It also discusses and evaluates the suitability of the locally composed kiln mortar and the products from the firing of the constructed kiln. The data for this chapter were gathered through observation of the entire project and tests conducted to confirm the suitability or otherwise of some of the products derived from the project. And this has been described below.

4.1 Findings on materials used

The low-density bricks

In all, 5 experiments were conducted. Experiments 1, 2 and 5 were the only compositions that satisfied the requirements of the project. Out of these, only the result of experiment 5 was considered for the project, because experiment 2 was found to be excessively porous and very delicate with very low tensile and compressive strength. On the other hand, experiment 1, showed considerably low porosity with an appreciable level of tensile and compressive strength. Experiment 5 was in-between 1 and 2 with acceptable physical properties necessary for the project. This composition was used for moulding all the local low-density bricks used in the project for the kiln.

This was made from a composition of equal volumes of Mfensi clay and sawdust. In this it was observed that the plasticity of the Mfensi clay was essential for the binding of the two materials forming the body. Compositions made from Mfensi clay type was unable to hold to form the brick when cast in the mould. This was contrary to the aged clay of the Mfensi type. The addition of deflocculant (sodium silicate) enhanced fluidity of the system, thus reducing the quantity of water required to convert the body into a mouldable mass.

The drying of the bricks was very slow compared to the rate at which bricks made from raw Mfensi clay dried. Although researcher speculated that drying of the body would be faster, holding on to the contention that, reduced amount of water was used because of the addition of the deflocculant (sodium silicate). On the contrary the clay sawdust body took a longer time to dry most probable due to the water retention properties of the sawdust. This however was substantiated by the growth of moulds on the brick which was made evident by the presence of moisture and carbonaceous or organic material (Plate 4.1).

Plate 4.1 Growth of fungus on the drying brick

It was observed that, after firing the bricks, they became very light in weight as compared to their green ware. The density of the fired bricks was reduced. The high porosity in the bricks produced was evidence of the presence of entrapped multitude of air pockets, which makes light porous bricks, an effective heat barrier and an excellent property of heat resistance. This was shown in the high percentage of water drawn into the brick when subjected to moisture absorption test.

Locally composed kiln mortar

This was the mortar that was used for the entire construction of the kiln. The material components of the mortar were plastic Mfensi clay, Kaolin, builder's sand and sodium silicate (deflocculant). This was able to hold the bricks for the construction. In the use of the mortar it was observed that due to the porosity of the bricks the bonding properties of the mortar and the brick was not good in giving level in the entire construction. It therefore became necessary for researcher to submerge the porous bricks until they are turgid before using them for the construction of the kiln. This treatment allowed better union of the bricks and the mortar thus giving strength to the joints. It became evident after the first test firing that the material selected for the composition was suitable when a scratch test with a sharp pointed nail on the dome of the kiln indicated advance hardness, a result confirming the fusion of the material as a result of the heat which was about 1000ºC.

4.2 Discussion of General Findings

Firing the kiln

The entire process of firing the kiln to bring its content to the point of maturity took about 8 hours. This involved preheating, which took 3 hours 30 minutes. During this period, there were visible signs of smoke appearing from the chimney of the kiln signalling incomplete combustion of organic materials mostly found in clay. There ware a bricks containing sawdust also being fired so that was another ground to suppose that combustible material is being fired under non-oxidizing condition.

After 3 hours thirty minutes of preheating, researcher increased the flow of liquefied petroleum gas into the kiln increasing the rate of combustion. This stage of firing lasted for 1hour 30 minutes. There was increased out put of smoke which was considered by researcher as the result of the sawdust present in some of the bricks being fired. The third stage of the firing lasted one hour. This stage experienced a reduction in the out put of smoke. It became evident that most of the combustible and organic materials present in the clay have been burnt out. At this stage there was a low glow of light in the kiln and this made visible some of the works parked in the kiln when one peeped through the spy hole. The fourth and final stage was described as the blast by the researcher. This stage witnessed very little smoke for a short time and there was no sign of smoke but flames running out of the chimney. At this stage anytime the damper of the kiln is pushed in the flames were redirected through the spy hole. At about an hour to the end of the process, the works in the kiln were seen as glowing pieces through the spy hole. The firing process was completed in the eighth hour. The gas valve was turned off. This did not initially reduce the glow in the kiln. The burner holes and dampers were cocked for heat retention and it took 24 hours for eventual cooling of the kiln.

Evaluation of fired works

Apart from a sculpture piece that was shattered in the kiln, all other works including the clay –sawdust brick were intact and were all fired to maturity. According to J K Amoah ceramic bisque wares fired to the point of maturity will ring when gently struck with a stone or a metal. This test was conducted on the pieces that were fired on opening the kiln. All the works apart from the brick, gave a ringing sound when they were put to the sound test. The brick was also subjected to porosity test suggested by Dr. Rudolf Steiner. The result of the water immersion test revealed that the brick has a porosity ratio of 1:1 that is porosity percentage is 50.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary

The firing of ceramic wares dates back to prehistoric times. Several methods and technologies have been used in the process of bringing green ware to the point of maturity. The art of pottery making and firing has been taught and practiced in schools for a very long time. Unfortunately contemporary methods like firing of pottery in kiln is still lacking in most schools, because most schools do not have and can not afford the facility. Experiments conducted indicated the likelihood of adopting local earthenware like Mfensi clay for composition into heat retention bodies for the construction of kiln for senior high schools. For this reason researcher adopted the following objectives:

1. To study the methods and processes in composing low-density bricks from local earthenware.
2. To compose low-density bricks from Mfensi clay.
3. To use the composed bricks for the construction of a gas-fired kiln.
4. To use the constructed gas-fired kiln for the firing of ceramic wares and evaluate its effectiveness.

To achieve these objectives, the researcher visited some brick factories to see at first hand the methods and the process adopted for the moulding of brick and construction of kilns

The researcher however reviewed the available literature, observed and conducted interview on 12 respondents working on kiln construction and the methods they adopted in the production of suitable bodies for kiln construction, teachers of ceramics and artisans working in clay. The experimental and descriptive methods of research were adopted for this project. Test results of the experiment and the products indicate that, all the objectives outlined, were achieved thus proving the possibility of the set research questions.

5.2 Conclusions.

Although positive results were achieved in the project like effective heat retention in the kiln, good firing time and evidence of maturity of fired work, these were not without problems. The most significant problem was the interruption of electrical power supply to the laboratory where the experiments were conducted. Almost all the material processing equipment in the laboratory were very old and this made processing of materials for experimental pieces very difficult. The researcher at a point had to use manual tools and improvised equipment to process the raw materials to carry out the project. The absence of an electric power generator to supply power to support the firing of test samples, milling and blending of materials, made it difficult for the researcher to conduct the experiment according to standard laboratory practice, and this led to manual manipulation of the compositions and lower firing temperatures in some instances. For this reason the researcher therefore did some of the test firing in commercial wood fired kiln while large scale firing was being done. This probably impacted negatively on the firing temperatures and fired effect of the samples. Obtaining adequate funding for the project was difficult and it caused delays in the purchasing of materials for the project. This was one of the limitations that made it impossible for the researcher to go beyond what has been described in the report. The study has shown that Mfensi clay is a suitable material base for bodies' required for kiln construction. It has also revealed that, the untapped locally obtainable raw materials must be studied to explore and exploit their potentials in art, art education and technology.

5.3 Recommendations.

1. Well equipped material science laboratories and workshops should be established in the University to encourage students to embark on viable projects that can yield results necessary for Ghana's industrial development.

2. Adequate funding should be made available to motivate students and researchers to undertake viable and sustainable projects.

3. This project report should be published and if possible, for easy access to all and copies be made available in libraries, educational centres throughout the country and to serve as an educational resource material for educational institutions offering ceramic art as a course of study.

4. Seeing that the adaptation of locally obtainable raw materials as principal engineering materials is a possibility, the construction of kilns using local materials should be encouraged to help reduce overdependence on expensive and imported kilns.

Implication for further research

The method adapted involves the use of pre-experimental procedures in research and this brings it to a state of lower validity and therefore sets the stage for further research.

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APPENDIX:

PICTURES OF FIRED WORKS


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